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L. O. HOWARD, Chief.

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RECENT EXPERIMENTAL WORK ON POISONING COTTON-BOLL WEEVILS.[1]

By B. R. Coad,

Entomological Assistant, Southern Field-Crop Insect Investigations, Bureau of Entomology.

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EARLY ATTEMPTS AT POISONING THE WEEVIL.

Practically since the advent of the Mexican cotton-boll weevil innumerable attempts have been made to control this pest by the use of poisons. The results, however, were always discouraging. The best that could be secured apparently was a very slight degree of control which would seldom pay for the expense of treatment. As a result it was generally conceded that the weevil could not be poisoned profitably under cotton-field conditions. This was attributed to the fact that the weevil derived its food from deep punctures which it made into the cotton squares and bolls, thus ingesting very little of the external plant tissues upon which the poison would be found. On account of this feeding habit of the weevil the idea prevailed that the only possible method of poisoning would be one which would so distribute the poison on the plant that small amounts would be eaten during the process of starting the punctures through the external tissues. For this reason all experiments were aimed toward getting a poison which could be driven inside the

[1] In the development of power machinery for applying the poison Mr. Elmer Johnson, of the Bureau of Public Roads, has been of inestimable assistance.

bracts surrounding the cotton square and on to the bud itself. In addition, a considerable portion of the experiments included principally treatments very early in the season before the squares had appeared. At this stage of growth the prime objective was to drive the poison into the terminal bud which forms the tip of the young cotton plant and which is the favorite weevil food before squares are formed. As has been mentioned, however, the results secured from all these attempts to poison the weevil were, generally speaking, very dubious and gave no apparent reason for hope for the successful poisoning of the weevil.

THE WATER-DRINKING HABIT OF THE WEEVIL AND ITS BEARING ON POISONING.

During the seasons of 1913 and 1914 the writer conducted a number of biological investigations on the boll weevil from which an intimation was obtained of the possibility of utilizing certain newly discovered features in an attempt to poison the weevil. It seemed quite obvious that there was no hope of successfully poisoning weevils if full dependence were placed on the amount of poison they would secure in the course of their feeding. These studies, however, demonstrated very clearly the importance of water to the continued existence of the weevil. It was found that under cage conditions they drank water very regularly and it seemed reasonable to assume that under field conditions they would secure this apparently essential moisture by drinking from the rain or dew collected in droplets on the leaves of the cotton plants. With this idea in view, the writer decided to conduct experiments in which the attempt would be made to poison the water which the weevils would drink.

THE POISONING TESTS OF 1915.

The first tests of this nature were instituted in 1915 and have been continued to date by the various agents of the Delta Laboratory of the United States Bureau of Entomology under the direction of the writer. The majority of these tests were located in the vicinity of Tallulah, La., which is in typical delta territory and normally subject to an exceedingly heavy degree of weevil injury due to the great humidity and excessive rains which prevail. For the purpose of these experiments of 1915, triplicate series of plats were surveyed on three different plantations near Tallulah. Each of these series consisted of five plats of about one acre each, as nearly uniform as possible in all conditions affecting their production of cotton. In each case the two end plats were given four, five, and six applications of poison, respectively. It was soon evident that this poisoning was exerting a very decided control on the weevils, as the weevil infestation was considerably reduced in the poisoned plats and these plats continued blooming much later in the season than did the adjoining unpoisoned

ones. When the cotton was picked from these plats rather surprising results were secured. Every poisoned plat yielded more than the untreated checks, but the most pronounced feature was the much greater increase in yield with the larger number of poisonings. With four applications a gain of about 15 per cent was secured; with five applications this gain was increased to about 35 per cent, while with six applications it was increased about 70 per cent. In other words, a single extra application over four more than doubled the gain, while two extra applications over four increased the gain between four and five fold. As all applications were started at the same time and the extra treatments consisted simply of a continuation that much later in the season, this seemed to point out very significantly the importance of late-season applications.

POISONING EXPERIMENTS IN 1916.

The results of these experiments were certainly definite and significant, but it was considered possible that they might have been due to some peculiar conditions prevailing during that season and that they could not be duplicated during another year. Consequently the experiments during the season of 1916 were planned largely to check the results secured during 1915, with the important change that provision was made for a wider range in the periods of application. In 1916 the applications in the different experiments extended from the first appearance of the weevils in June until about the 1st of September. On the whole the results in 1916 were just as definite as were those of 1915, and the greater importance of the late-season applications was very plainly demonstrated. In this connection a detailed description of a few of the tests is of interest.

Probably the most spectacular test of the season and the one which aroused the most interest was conducted in a cut of abandoned cotton. Poor drainage and excessive rains during May and June had prevented cultivation of this cut, and on the 25th of July there were no prospects whatever of a crop. The plants were only about 10 inches high and had been so heavily infested by the weevils that there had been no blooms since June. Thus an opportunity was afforded to determine what could be accomplished by poisoning under the most extreme conditions imaginable. An attempt was made to work the cotton out about the 1st of August and a small plat in the center of the cut, only six-tenths of an acre in size, was poisoned. This poisoning was continued during the month of August and surprising results were secured. The weevil infestation decreased rapidly in the poisoned plat and the plants soon started blooming and continued to bloom practically until frost in spite of the fact that all surrounding cotton was very heavily infested with weevils and undoubtedly hundreds, if not thousands, were moving into the

poisoned cotton daily. When the cotton matured a remarkable sight was presented. The unpoisoned cotton showed practically no open bolls, while the poisoned plat to the very last row was practically white with open cotton. This is illustrated in figures 1 and 2, which show different views of the dividing line between the poisoned and unpoisoned cotton shortly after the first killing frost. When the cotton was picked it was found that the unpoisoned plats yielded 45 and 65 pounds of seed cotton per acre, respectively, while the poisoned plat yielded about 500 pounds per acre. This, of course, did not constitute a good yield of cotton but was very remarkable in view of the opportunity which this cotton had had to produce a crop.

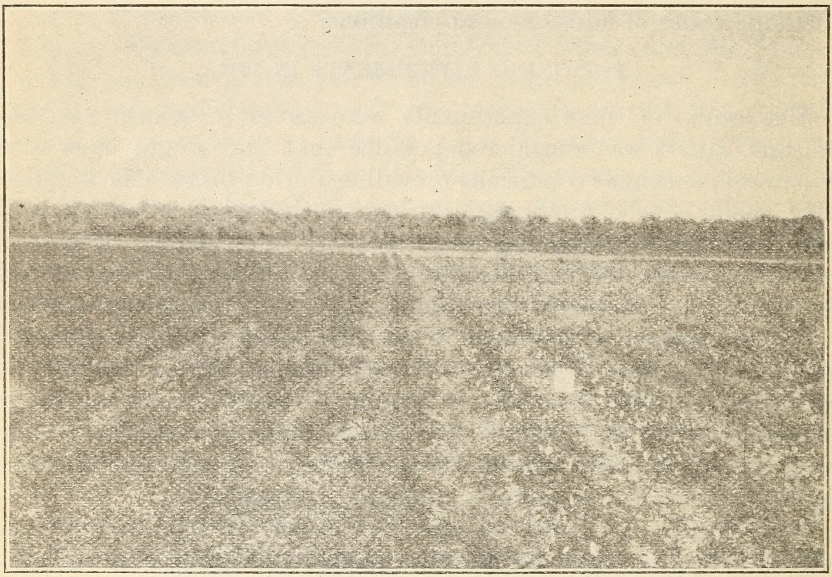

FIG. 1.—View showing dividing line between poisoned and unpoisoned cotton on Algodon Cut No. 1 October 30, 1916, Tallulah, La. Beginning of additional unpoisoned cotton can be distinguished at upper right-hand corner of view.

This test was particularly interesting because of the severe conditions which prevented the unpoisoned cotton from making any production, because the plants were so small, and because it was possible to poison the last row of the treated plat effectively without allowing the poison to drift on to the adjoining check row. For this reason the line of demarcation between the plats was much more pronounced than usually was possible.

Additional tests during the same season located in better cotton frequently gave larger gains in production per acre, but of course the percentage of gain was not so large. In one case of poisoning during the month of July a gain of about 600 pounds of seed cotton per acre was secured. Figures 3 and 4 show a comparison of the typical

picking in the poisoned and check plats, respectively, in this test. In this case the cotton was so luxuriant that the dividing line could not be shown in a single picture, but the two views given in these illustrations were selected by a disinterested planter as being typical of the two plats. Probably the most interesting feature of this test was the fact that there were 22 days of rain during the month when the applications were made. This seemed to indicate that successful results could be secured from poisoning in spite of excessively rainy weather and tended to allay the fear that dry weather would be essential to successful results.

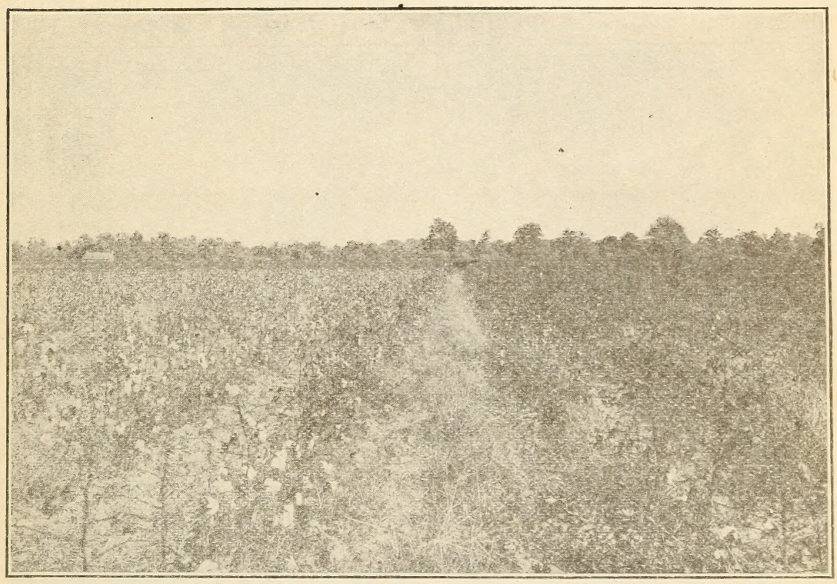

FIG. 2.—Another view showing dividing line between poisoned and unpoisoned cotton on Algodon Cut No. 1, October 30, 1916, Tallulah, La. View looking in opposite direction from that shown in figure 1.

In another case a portion of a cut of new ground practically surrounded by heavy timber was poisoned. This was very heavily infested with weevils, but the poisoned plat yielded about 1,700 pounds of seed cotton per acre as compared with about 900 for the check. The treatments in this case were practically confined to late July.

In all about 15 experiments were conducted during 1916, and the total results showed definitely that it was possible to poison the weevils profitably under certain conditions. Again, the increased value of late-season applications was obvious, for, as a general rule, the early-season applications gave only slight gains with a very doubtful profit whereas the late-season applications all showed pronounced profits.

EXPERIMENTS IN 1917.

EXPERIMENTS AT TALLULAH, LA.

At the beginning of the season of 1917 it was recognized that the experiments to date had merely demonstrated the possibility of poisoning weevils successfully, and that all phases of the economic use of the poison remained still to be worked out. Consequently a very elaborate series of experiments was inaugurated in that season, and about seventy-five tests were started in the neighborhood of Tallulah, each one intended to determine some particular point of importance. These consisted of studies of the comparative efficacy of different poisons, the time of day of application giving the best results,

FIG. 3.—Typical view of opened cotton in poisoned plat on Algodon Cut No. 2, second picking, October 12, 1916, Tallulah, La. For comparison with figure 4.

the most profitable season of application, the proper interval between applications, the requisite amount of poison per acre, and many other similar questions, all of which would have to be answered before definite general advice as to the use of the poison could be given. The early studies had shown that under certain conditions poisoning was profitable, but it was apparent that any change in these conditions might easily result in a much lower gain, if not in an actual loss, and it was essential to determine thoroughly the possibilities and limitations of boll-weevil poisoning before releasing any information for public use. Unfortunately for the experimental work, the season of 1917 in the vicinity of Tallulah was most remarkable for the light degree of weevil damage. This was due to a peculiar com-

bination of seasonal conditions and resulted in an almost complete absence of weevil damage in all of the cotton in which tests had been planned. In other words, the yield of cotton in these cuts was just the same as if no weevils had been present. Of course weevil-control experiments could not be conducted under such conditions and the majority of the Tallulah experiments had to be given up for the season. Nevertheless, a dozen or more cuts were located immediately adjoining timber where a somewhat heavier degree of infestation was experienced, and in these cases the rule prevailed that the heavier the infestation, the greater the gain due to poisoning. These results, of course, fully confirmed those of the preceding two years, but the necessary postponement of many experiments still left many

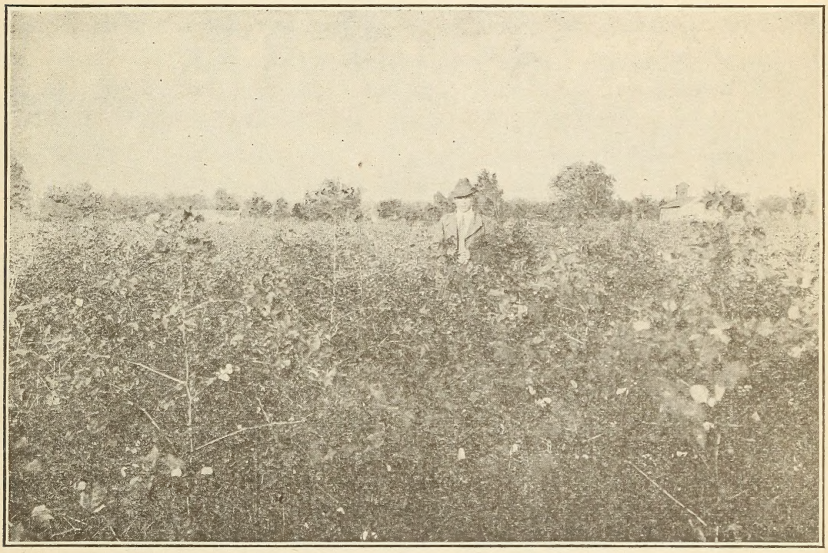

FIG. 4.—Typical view of opened cotton in check plat on Algodon Cut No. 2, second picking, October 12, 1916, Tallulah, La. For comparison with figure 3.

gaps in the information essential to outlining a general procedure for weevil poisoning.

Figure 5 illustrates something of the results secured in one of the more heavily infested cuts near Tallulah. This photograph was taken to show the difference in the amount of top cotton produced by the poisoned and unpoisoned plats, and shows only the second picking. A considerable gain had already been secured at the first picking, and in the total a gain of something over 50 per cent was secured.

EXPERIMENTS IN ARKANSAS AND MISSISSIPPI.

In addition to the experiments just detailed, a number were conducted in the North Delta, in Chicot County, near Lake Village, Ark., and in Washington County, near Scott, Miss. At both of these

points a heavier infestation was produced by different seasonal conditions, and pronounced results were secured from the poison. In every case the experiments were conducted on comparatively small areas, subject to a continual influx of weevils from surrounding untreated cotton, but in spite of this a very definite weevil control resulted from poisoning. The open cotton in every case showed a definite gain to the last row of treatment. The gains per acre ranged from 250 pounds to 1,007 pounds of seed cotton. Views of two of these tests are shown in figures 6, 7, and 8.

It is, of course, impossible to estimate how much larger these gains would have been if entire cuts or entire plantations had been

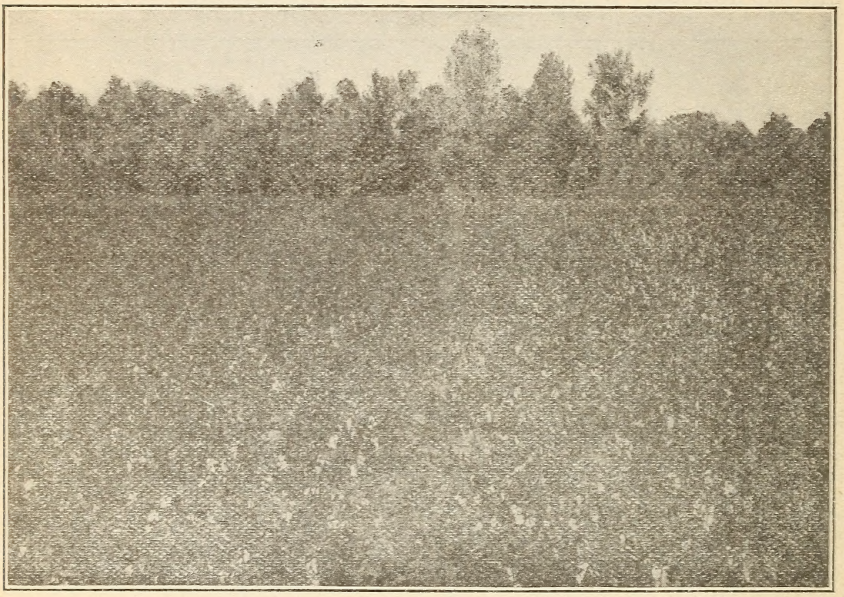

FIG. 5.—View looking across rear end of poisoned cotton on Mound Plantation Cut No. 2, with poisoned cotton on right of view and unpoisoned on left; second picking only, October 23, 1917, Tallulah, La.

treated, and thus the inflow of weevils from unpoisoned cotton prevented, but it is clear that these gains secured on small plats were very conservative. In fact, this was brought out well by one large-scale treatment described below.

A LARGE-SCALE TREATMENT.

About the middle of August the writer was requested to attempt the control of the weevil on a large section of an Arkansas plantation. This cotton was on very fair land, but had not been planted until well along in May. Weather conditions then retarded it greatly and it did not start setting a crop until about the latter part of July. About the middle of August a fair crop of bolls was present, but the plants were

large and leafy and the weevils had multiplied so rapidly that one of the heaviest infestations ever witnessed by the writer prevailed. Blooming had practically ceased and the weevils had cleaned up the squares so thoroughly that they were attacking the bolls in enormous numbers and all bolls, even to the largest present, were being riddled with punctures. It seemed probable that on one section no bolls would be left to open. It was, of course, too late to attempt to set a new crop by poisoning, but an effort was made to save the bolls then present on the plants. For this purpose large-scale treatments were continued from August 23 to about September 1, several hundred acres in all being treated. At the beginning of the work a series

FIG. 6.—View along dividing line between poisoned and unpoisoned cotton in Lake Vista Cut No. 2, with poisoned cotton to left of view; second picking only, October 26, 1917, Scott, Miss.

of counts showed that 86 per cent of the squares in the cotton which was to be poisoned had been weevil-punctured. This cotton was given a single poisoning and, about 10 days later, it was found that the weevil infestation in these same cuts had been reduced so that only 36 per cent of the squares were punctured. During the same period the infestation in the adjoining unpoisoned cotton had been increasing steadily. Practically all of the poisoned cuts started blooming again at this time and a number of them reached what is ordinarily termed the "flower-garden" stage of blooming, five to seven blooms per plant on a single day being not at all rare. In starting this treatment it had been anticipated that several applications would be necessary to produce the desired result, but

the effect of the single application was so pronounced that it seemed unnecessary to repeat it. The weevils had been so reduced that only 36 per cent of the squares were punctured, and although thousands of weevils were being bred out from the squares on the ground or were coming in from other plantations every day, it was still obvious that the weevils would greatly reduce their attack on the bolls until they had caught up with the squares then present, and that this period would be long enough to allow the bolls to become sufficiently hardened to avoid weevil damage. Owing to the necessity of poisoning considerable areas in this case and to the inability to leave unpoisoned plats as checks, it was of course impossible to determine the exact

FIG. 7.—View down center of check plat, Isola Cut No. 1, on October 26, 1917, showing cotton available for second picking; Scott, Miss. For comparison with figure 8.

benefit derived from the treatment. Rough comparisons, however, based on yields of surrounding cuts, made it obvious that a considerable gain had been secured and it was evident that the poisoning was a very profitable operation.

LABORATORY AND OTHER EXPERIMENTS.

Numerous other field experiments might be detailed to add weight to the results secured, but the ones described have been selected as illustrating the different methods followed and the different conditions experienced, and are surely sufficient to illustrate the effectiveness of the poison. In addition to these field tests a number of laboratory studies were conducted at the same time to check the

results in the field. These were conducted under cage conditions and were for the purpose of comparing the effectiveness of different poisons and different methods of poisoning.

IMPORTANCE OF MOISTURE IN POISONING.

One interesting feature of the foregoing tests was the apparent necessity of the presence of moisture if any considerable degree of weevil mortality were to be caused by the poison. It was found that only a very light mortality would result from tests where the plants were kept absolutely dry after poisoning; but as soon as moisture was introduced the mortality increased tremendously. This evi-

FIG. 8.—View down center of poisoned plat, Isola Cut No. 1, on October 26, 1917, showing cotton available for second picking; Scott, Miss. For comparison with figure 7.

dently validated the conclusion that at least a major portion of the success in poisoning was due to ingestion by the weevil while drinking.

RELATIVE EFFECTIVENESS OF DIFFERENT ARSENICALS.

In the course of these experiments quite a number of different poisons were utilized and it was found that nearly all arsenicals were effective to a certain degree but that most of them were not sufficiently effective to be satisfactory. At the outset the ordinary triplumbic form of lead arsenate was utilized. It was found, however, that this was not sufficiently toxic to the weevils to warrant its use and the newer dihydrogen form of lead arsenate proved to be vastly more toxic. This was utilized in practically all of the experiments of 1916, but additional tests demonstrated that a high grade

of calcium arsenate was still more effective. This contains a much higher percentage of arsenic pentoxid than any other arsenical utilized and has the great advantage of being much cheaper than lead arsenate. In addition, a number of tests of various mixtures of these arsenicals and dilutions of them with different carriers were conducted. This work is still in the experimental stage and it is difficult to prophesy just what the results will be. It is obvious, however, that either a dihydrogen lead arsenate containing not less than 32 per cent of arsenic pentoxid or a calcium arsenate containing at least 42 per cent of arsenic pentoxid will produce an effective control if utilized properly. It also seems probable that it will

FIG. 9.—Hand dust guns in operation, showing method of use; Tallulah, La., July 15, 1916.

be possible to dilute these considerably with some cheap carrier such as lime, though this has not been definitely determined as yet.

DENSITY OF THE POISON.

Fully as important as the actual composition of the chemical is its physical condition. When the experiments were first started, practically all of these chemicals were prepared only in a density of about 40 cubic inches per pound. It was evident, however, that a much finer powder would afford a greater distribution per pound, and also that a finer powder was apparently more readily taken up by the dew and held in suspension for the weevils. Consequently these poisons were prepared in density ranging from 80 to 160 cubic inches per pound and proved much more effective in that form.

TIME OF APPLICATIONS.

WHEN TO BEGIN POISONING.

The technique of application is obviously much more important than the actual poison utilized, if a poison of satisfactory degree of toxicity be selected. As has been mentioned, very doubtful profits were shown by early-season applications, and the most definite gains resulted from treatments made while the infestation was at its height. This is evidently due to a combination of conditions which need not be discussed in detail here, but which caused an application made at the time the weevils were doing their maximum injury to the crop to be far more effective in their control. This time, of course,

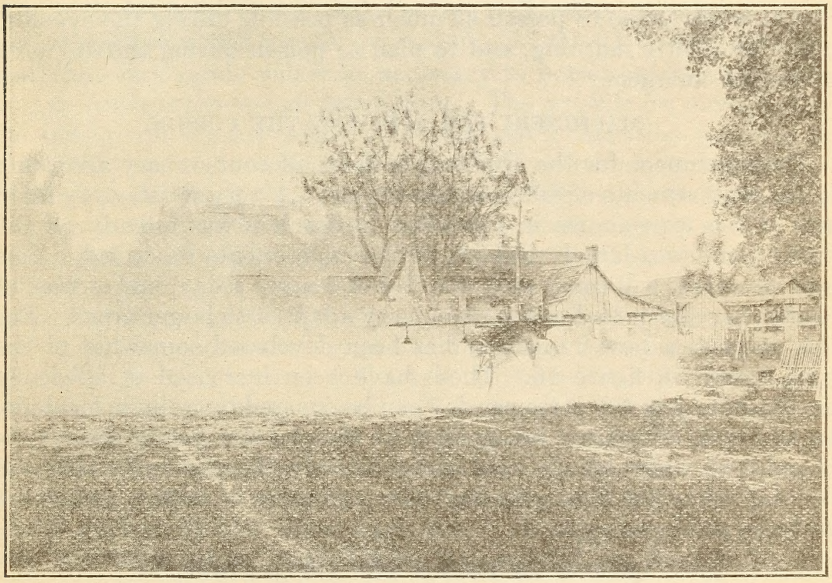

FIG. 10.—Power dusting machine in operation at Tallulah, La., April 26, 1917, showing type of dust fog developed.

varies considerably under different conditions and in different seasons, but is usually the time when the cotton manifestly slackens in blooming, and, while the experiments are not yet completed to the point of outlining definitely just when the most effective season of application will be, it will probably be found to be at about this time.

INTERVAL BETWEEN APPLICATIONS.

The time interval between applications is another important point which must be determined but concerning which comparatively little is known as yet. In most of the tests conducted so far the applications have been repeated at weekly intervals more as a matter of convenience than for any particular reason, but it seems probable that about once a week will constitute an effective application.

TIME OF DAY.

Another question of importance is the time of day for application. It is, of course, well known that much more effective poisoning with dry dust can be conducted while the dew is on the plant, as the poison not only clings to the plant better but has much less tendency to drift away from the cotton. A number of tests have been conducted in an attempt to secure some information on this score but were so hampered by the light infestation of 1917 that definite conclusions are not warranted. It is evident that more effective poisoning usually can be done from about 4 p. m. until about 9 a. m. than at other times, although fairly successful results have been secured from applications made throughout the day. It will probably be found that it is advisable to poison as much as possible during the evening, night, and early morning, and to plan to poison during the day only in case of emergency.

MACHINERY FOR APPLYING THE POISON.

The machinery for the application must, of course, vary according to the requirements of different conditions. A very satisfactory hand gun of the type shown in operation in figure 9 was already on the market and was largely utilized in the experiments described. This gun, however, will cover only about 4 or 5 acres a day, and it was, of course, necessary to develop machinery adapted to larger areas. For this purpose a power machine has been developed somewhat of the type shown in figure 10. These have been increased in efficiency until now nearly 200 acres per day can be covered by a single machine. In addition, efforts are being made to develop an intermediate type of machine which can be sold comparatively cheaply and which will be adapted to the man planting 50 to 100 acres of cotton, and cover 20 to 30 acres per day.

AMOUNT OF POISON PER APPLICATION.

The amount of poison required per application has depended so far more on the requirements of the machinery utilized than on the amount necessary for thoroughly dusting the cotton. As a general rule experimental applications have averaged about 5 pounds per acre, but it is apparent that this amount is excessive, and with further improvement in the machinery it will be possible to accomplish an effective poisoning with a much smaller amount.

NUMBER OF APPLICATIONS.

The number of applications necessary undoubtedly will vary. This must depend entirely on the conditions prevailing within the particular cut under consideration. In most of the experiments conducted so far from three to five applications were made but, as has been shown, the effectiveness of these was considerably reduced by the fact that they were on such small plats. In the only case in which experiments on a very large scale were conducted, the effect

of a single application was as pronounced as is ordinarily secured from about three applications on a small plat, due, of course, to the constant migration of weevils into the small plat

COST OF TREATMENT.

The cost of treatment will, of course, vary widely. In the strictly experimental tests conducted so far it has averaged usually about $1 an acre for each application. It must be recognized, however, that it will be possible to reduce this considerably when applications are made on a larger scale, and, with improved machinery, a further reduction will result from the lessened poison requirements. In addition, the probability that it will be possible to utilize carriers and thus further reduce the amount of poison required per acre renders the cost subject to a still greater reduction. It should be remembered, also, that very rarely will it be necessary to poison an entire plantation to control the weevil infestation. The weevils on emerging in the spring will always concentrate near the hibernation quarters in which they spent the preceding winter. They remain rather closely at these points until they have multiplied sufficiently to threaten a shortage in the local food supply. For this reason a great part of the cotton is not seriously infested with weevils until some time after midseason and often not until well along in August. Of course the control measures adopted must depend on conditions on each plantation, but by concentrating on the more heavily infested cuts just before the weevils become sufficiently abundant to start movement to the remainder of the cotton it will be possible not only directly to benefit the cotton treated, but to protect the remainder of the plantation by preventing the weevil migration. In this way the cost of the treatment for a comparatively few acres will be borne by the benefit derived by the entire plantation. In this connection it probably will often prove advisable to give several applications to the more heavily infested cuts and perhaps only a single application to the remainder.

NECESSITY FOR FURTHER EXPERIMENTAL WORK.

In conclusion it should be emphasized that the present bulletin is merely a "progress report" and the writer does not wish to be construed as in any way advising the general use of these poisons for boll-weevil control. There are now too many doubtful points, especially as regards the technique of application; and, as has been shown, the technique of application largely determines the benefits derived. At the present stage of the investigation it is impossible to outline a definite plan of procedure for the poisoning of weevils under all conditions, and much more experimental work will be required before such a plan can be proposed. With the present lack of information on so many important points, any attempt to poison the weevil by the inexperienced may very easily result in actual loss.

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